EVALUATION OF SORBENT USE FOR RETRIEVAL OF HAZARDOUS SUNKEN LIQUIDS

by

Beverley Ross
University of Waterloo
Waterloo, Ontario

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River Road Environmental Technology Centre
Ottawa K1A 0H3

EE-97

December 1987

ABSTRACT

A variety of commercially available sorbent products were tested using six liquid chemicals all with a density greater than that of water.The sorbents were tested both in test liquid alone and test liquid sunk in water and were evaluated for capacity, water pick-up and number of reuses.Changes in sorbent performance in flowing water conditions were also examined.

The polypropylene,polyethylene,and cross-linked polymer bead sorbents showed the greatest potential for sunken chemical recovery.These sorbents had higher capacities,greater chemical resistance and lower water pick-up than the other sorbents tested.Greatest reusability was demonstrated in the polypropylene and polyethylene sorbents.

With few exceptions, the performances of those sorbents tested in flowing water were not significantly affected under the testing conditions used.

RESUME

L'étude a porté sur huit sorbants différents; il s'agissait de déterminer leur efficacité pour six produits chimiques liquides plus dense que l'eau. Les sorbants ont été évalués en laboratoire dans les produits chimiques purs et dans les produits chimiques coulés dans un volume d'eau statique. Leur capacité initiale, leur rétention d'eau et leur réutilisation ont été mesurées. Leur efficacité dans une eau en mouvement a également été évaluée.

Les sorbants de polypropylène, de polyéthylène et les billes de polymère entrecroisé ont démontré un plus grand potentiel d'utilisation pour la récupération de produits chimiques coulés dans une nappe d'eau. Une plus grande capacité, une plus grande résistance à la destruction par les produits chimiques et une plus petite rétention d'eau ont été mesurées pour ces sorbants. Un plus grand nombre de réutilisation a été possible avec les sorbants de polypropylène et ceux de polyéthylène. A quelques exceptions près, l'efficacité des sorbants évalués dans un volume d'eau en mouvement plutôt que dans une eau statique, n'a pas sensiblement changée.

ACKNOWLEDGEMENTS

This report was submitted as a work term report to Conservation and Protection of Environment Canada. H.Whittaker and F.Laperriere of the Environmental Emergencies Technology Division, were the scientific authorities for this report.

This report was prepared by B.Ross. Thanks are extended to H.Whittaker and F.Laperriere for their help in its preparation,and to Jill Worry for her help with the typing and tables.

A sample of the coal tar found at the bottom of the Rideau River in Ottawa was provided by Integrated Explorations while working with Proctor and Redfern.

Perchloroethylene "puddle" material from the bottom of the St.Clair River near Sarnia,Ontario was provided by Dow Chemicals of Canada.

The sorbents were provided by their respective manufacturers and distributors.

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CONCLUSIONS

Sorbent use for recovery of sunken hazardous chemical spills shows sufficient promise to be studied further.

Polypropylene and polyethylene synthetic polymer sorbents, as well as cross-linked polymer beads, were the most successful sorbents tested in this study. These sorbents exhibited high capacity, low water pick-up, and little release of sorbed chemical on retrieval.

Polyurethane, treated organic fibre and activated carbon sorbents have various shortcomings that don't recommend them to use for sunken chemicals recovery.

The performances of those sorbents tested in flowing water (Conwed, Matasorb,Conwed-D, and Imbiber Beads) were not adversely affected to a significant degree by the low current in which they were tested.

RECOMMENDATIONS

Study should be continued on a larger scale with simulated field conditions that include variations in current velocity, water depth, and wave height.

A method of physically measuring release of sorbed material into water by sorbents during retrieval should be developed for further testing.

Other synthetic materials (polyester,polyether etc.)should be examined in future.

A greater variety of deployment methods should be developed and studied.

1 INTRODUCTION

The production and use of sorbents for spills clean-up is currently limited to oil and chemical spills on land and afloat on the water's surface.However, the increasing number of sunken insoluble chemical spills discovered in Canada has prompted the search for new technologies for recovery of chemicals from the bottoms of water bodies.

One of the methods currently being investigated at Environment Canada's Environmental Emergencies Technology Division is the use of sorbents to contain and retrieve these hazardous chemicals.

The most popular spill countermeasures presently being employed for sunken liquids are(1):

1) Capping and Burial-usually with clay,sand or diatomaceous earth.This method has the following disadvantages;the possibility of spreading the spill further;profound changes in the bottom topography destroying the local benthic organisms;and,that, after a period of time,leakage could occur recontaminating the surrounding area.

2) Suction Dredging-the most common technology in use and currently the most effective.The major disadvantage of this method is the requirement for on-site treatment of dredged materials.Water and solid material must be separated from the organic spill chemical and treated further before being returned to the environment. Furthermore,dredging may cause resuspension of the spilled chemical as well as disturbing bottom topography and benthic organisms.

This study examines the use of sorbents on sunken chemicals on a laboratory scale. Evaluation of all the parameters involved in the field use of sorbents(eg.weather and water conditions,etc.) is beyond the scope a laboratory study. However, this study will provide both a quantitative and a qualitative evaluation of the feasibility of sorbent use for sunken chemical spills recovery as well as point the direction for larger scale investigations.

1.1 Sorbents Tested

Previous EPS studies on sorbent use for floating spills (2,3,4,5) were used as a guide to the selection of sorbents that might be most successful in sunken chemical spills recovery. Sorbents were also selected to examine a variety of materials. The sorbents studied are shown in Table 1.

TABLE 1 SORBENTS TESTED

Sorbent Brand Name	Material of Construction
Graboil	treated polyurethane foam
Conwed-D	closed-cell polyethylene foam
Matasorb	polypropylene fabric
3-M Type 156 Pads	polyethylene fabric
Dow Imbiber Beads	cross-linked polymer beads
Conwed Pad	treated natural fibre reinforced with polypropylene mesh
Oclansorb	treated natural peat fibre
Calgon Granular Activated Carbon	type F-300 8*30

1.2 Study Parameters

The sorbents in this study were tested for ability to pick-up organic chemicals when brought into contact with them beneath the water's surface.

Six test liquids were chosen from EETD's list of priority pollutants.Two of these were reagent chemicals (1,2 dichloroethane and 1,2,4 trichlorobenzene), two household chemicals (creosote and latex) and two were authentic spill samples (perchloroethylene "puddle" material found in the St.Clair river near Sarnia.Ontario and coal tar found in the Rideau River in Ottawa,Ontario).

The following parameters were studied for each sorbent-liquid combination:

Sorbent Capacity (g test liquid/g sorbent): The amount of test liquid picked up by the sorbent after exposure.

Water Pick-up (% water by volume): Proportion of water picked up by sorbent during exposure to liquid in water.

Reusability: The number of times the sorbent can be pressed and used again.

2 LABORATORY EVALUATION

The procedure used during this evaluation was developed from previous studies on sorbents (2,3,4,5,6) as well as the ASTM proposed standard methods for sorbent testing (ASTM F716-82).

2.1 Materials and Apparatus

Standard laboratory glassware

Balance (Mettler P1200,see Figure 2.1)

Carver Laboratory Press (Model B,Figure 2.2)

Squeezing Piston

Centrifuge (Fisher #37277H) with calibrated tubes (Figure 2.3)

Viscometer (Brookfield Synchro-lectric Model LVT)

Reinforced glass tank (45 L,Figure 2.4)

Polypropylene tank (45 L,Figure 2.5)

2 Rotary Pumps (Cole Parmer,Model C-3250P,Figure 2.6)

Sorbents (see Table 1)-equipped with split-shot sinkers and fishing line guide-lines (Figure 2.7)
-activated carbon was packaged in Tetley brand teabags
-Imbiber Beads were packaged in teabags made from the packaging of the large pads

Test Liquids:

1,2-Dichloroethane (Fisher Certified A.C.S)

1,2,4-Trichlorobenzene (Fisher HPLC Grade)

Creosote

Latex

Perchloroethylene "puddle" material from St.Clair River near Sarnia,Ontario.

Coal Tar from bottom of Rideau River in Ottawa,Ontario

Rideau River water

Tap water

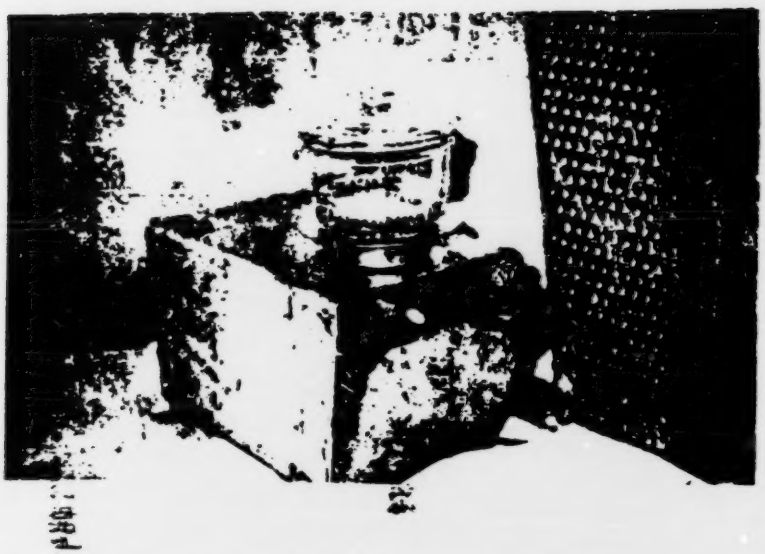

FIGURE 2.1 Testing Balance (Mettler P1200)

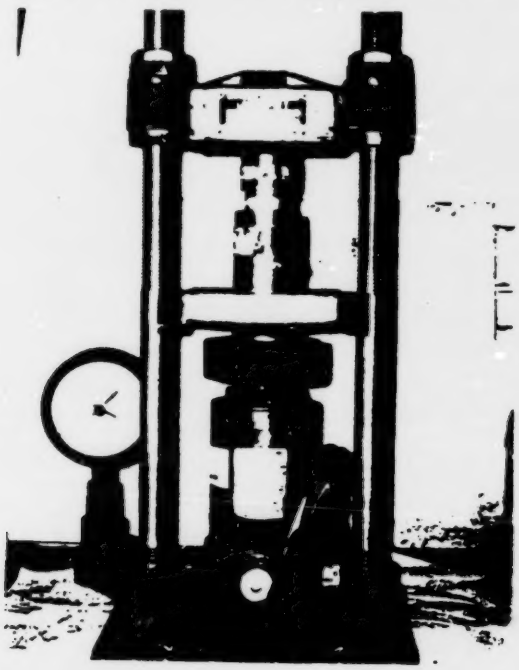

FIGURE 2.2 Laboratory Press (Carver B) and squeezing piston

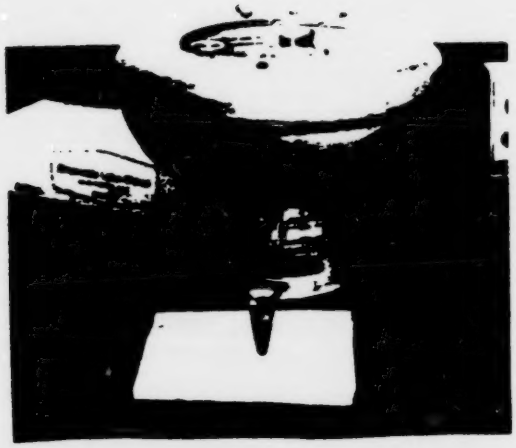

FIGURE 2.3 Centrifuge with Calibrated Tubes

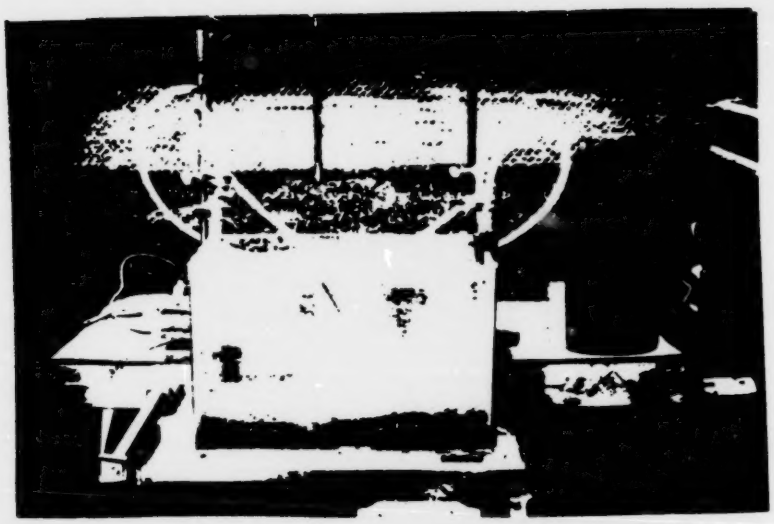

FIGURE 2.4 Reinforced Glass Tank

FIGURE 2.5 Polyethylene Tank

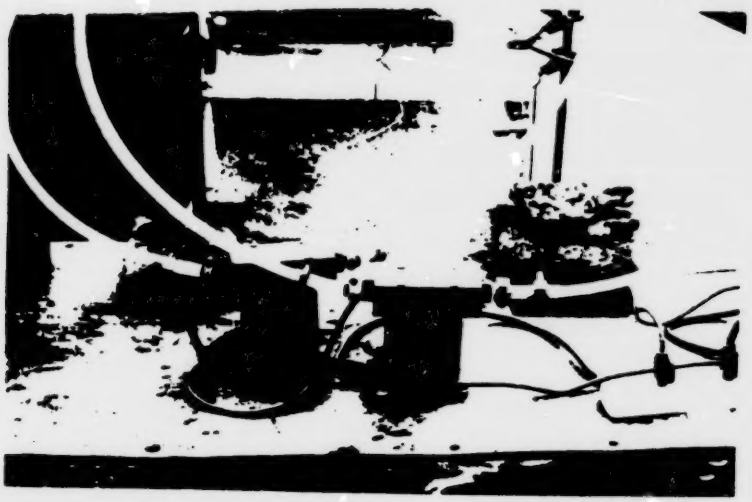

FIGURE 2.6 Rotary Pumps

FIGURE 2.7 Sorbent and Packaging with sinkers

2.2 Procedure

All test liquids were used as received with no subsequent treatment.

Red oil dye was used to colour those liquids that were colorless to render them more visible.

All samples were approximately 1g except the Imbiber Bead (2.5g) and activated carbon (5g) teabags.

Viscosities were measured at 15 °C (except 1,2,4-trichlorobenzene which was measured at room temperature (26 °C) on a Brookfield viscometer. Densities were measured at room temperature (22 °C).

2.2.1 Evaluation of Sorbent Capacity in Test Liquid Alone

Each sorbent was preweighed, then submerged for one hour in enough liquid to completely cover the sorbent after saturation (preliminary testing showed that one hour was sufficient to saturate sorbents).

All liquids (except 1,2,4-trichlorobenzene) were brought to 10 °C before testing and maintained in a refrigerator at 10 °C during testing. 1,2,4-trichlorobenzene was tested at room temperature (22 °C) as this liquid solidifies at 17 °C.

After the one hour soak time the test sorbent was removed and allowed to drip until dripping slowed to 1 drop/15sec, then weighed.

Duplicate samples of each sorbent-liquid pair were run and if the two results were not within 10% of each other a third sample was tested.

Sorbent capacity in liquid alone was calculated as follows:

$$\text{Capacity} = \frac{(\text{weight of test liquid and sorbent after exposure}) - (\text{weight of sorbent before exposure})}{\text{weight of sorbent before exposure}}$$

2.2.2 Sorbent Capacity for Test Liquid Sunk into Water

Duplicate samples of each sorbent were preweighed and sunk into the test chemical in water for one hour at 10 °C. As in the first test(2.2.1), sufficient test liquid was added to the water to completely cover and saturate the sorbent. Following the sorption period the sorbent was retrieved and allowed to drip until the dripping had slowed to 1 drop/15 sec,then weighed.The sinkers were then removed from the sorbent and the liquid pressed from it at a maximum pressure of 3425 kPa (500psi). The pressed liquid was collected in a calibrated centrifuge tube and centrifuged at medium setting for at least five minutes.

Following centrifugation, the volume of each separated liquid was measured.

After the pressing the sorbent was reweighed and returned, if possible, to the test liquid for reuse.This cycle was repeated until the sorbent capacity dropped to half the original capacity or the sorbent collapsed. A maximum of ten reuse tests were conducted for each sorbent.

As pressing was not possible for Imbiber Beads or activated carbon, water pick-up data from part 2.2.1 was used to estimate the water sorbed for these sorbents in the following manner:

Estimated mass of water sorbed (for activated carbon and Imbiber Beads) =

sorbent capacity for water (g/g from 2.2.1) * sorbent weight

Sorbent Capacity (for activated carbon and Imbiber Beads) =

$$\frac{\text{(weight of total liquid and sorbent after exposure)} - \text{(initial sorbent weight)} - \text{(estimated mass of water sorbed)}}{\text{initial sorbent weight}}$$

These calculations include the additional liquid sorbed by the packaging material. Activated carbon and Imbiber Beads have been shown by their manufacturers to have a preference for organic compounds over water and it is thus likely that the above estimations of water sorbed are greater than the true values.
For the remaining sorbents the Sorbent Capacity and Water pick-up were calculated in the following manner:

Assumption: Recovery of the liquid sorbed was not 100% but the assumption was made that the liquid remaining in the sorbent had the same composition as the liquid recovered.
In all calculations the density of water is not included as it is approximately equal to 1.0 at room temperature.

Sorbent Capacity = proportion by weight of test liquid sorbed * the total weight of liquid of liquid sorbed / weight of sorbent tested =

$$\frac{\%\text{ test liquid sorbed (by volume)} * \text{density of test liquid}}{\%\text{ test liquid sorbed} * \text{density of liquid} + \%\text{ water pick-up}} * \frac{(\text{weight of test liquid,water, and sorbent after exposure}) - (\text{initial sorbent weight})}{\text{initial sorbent weight}}$$

$$\%\text{ Water Pick-up} = \frac{\text{water volume sorbed} * 100}{\text{total liquid volume sorbed}}$$

Qualitative observations such as release of chemical into water during retrieval and integrity of the sorbent after use were also made.

2.2.3 Sorbent Capacity for Test Liquid in Flowing Water

To test and compare sorbent performance under flowing water conditions with a gravel bottom, a ten gallon glass aquarium was equipped with a flowing water system as shown in Figure 2.4. The tank was reinforced at the seams with silicone rubber caulking and silicone grease.

The flowrates for both pumps were set at 33 ml/sec bringing the total flowrate to 66 ml/sec and generating an observed current just beneath the surface of the water of approximately 14 cm/sec. The small size of the tank generated weaker currents in other areas as well.

Since the flowing water trials were conducted outdoors to provide adequate ventilation, the experimental temperatures could only be kept to 20°C - 25°C.

A depression was created in the gravel at the bottom of the tank and sufficient test liquid was added to more than saturate the sorbent.

As before, sorbents were exposed to the sunken liquid in water for one hour. As the sorbent was retrieved, it was moved across the outlets of the flow system to experience maximum current, at which point the sorbent was observed for release of chemical into the water.

The sorbent was treated after removal as in 2.2.2 with the following exceptions:

1) Since wind conditions could not be controlled and thus evaporation would be highly variable, the sorbent was only allowed to drip for approximately five seconds before being transferred into a closed weighing container.

2) Reusability was not tested during these trials.

The following sorbents were selected for testing in flowing water: Conwed, Conwed-D, Matasorb and Imbiber Beads. The following liquids were selected for the flowing water tests: 1,2-dichloroethane, St. Clair River perchloroethylene "puddle" material, and 1,2,4-trichlorobenzene.

When perchloroethylene was used as a test material, it was necessary to use a polyethylene test tank as the liquid was able to penetrate the seals in the glass tank.

The parameters measured were capacity and water pick-up.

2.2.4 Fate of Small Spill in Tank

To further test the feasibility of sorbent use, an amount of test liquid calculated to just saturate the sorbent tested was applied to the flowing water-gravel bottom tank as set up for 2.2.3. Following a five minute waiting period after liquid entry into the system the sorbent was applied and allowed to sorb for 30 minutes.

Volume of Liquid Applied =

$$\frac{\text{sorbent capacity} * \text{sorbent weight}}{\text{density of test liquid}}$$

The amount of test liquid recovered was determined by weighing and pressing. The percentage of test liquid recovered (by weight) was calculated as followed:

% Recovery = proportion of test liquid (by weight) * weight of liquid sorbed / weight of liquid applied

$$= 100 * \frac{\dfrac{(\%\ \text{test liquid(vol)} * \text{density of test liquid})}{(\%\ \text{test liquid} * \text{density of test liquid} + \%\ \text{water})} * (\text{weight of sorbent, water, and test liquid after exposure}) - (\text{initial weight of sorbent})}{\text{weight of test liquid applied}}$$

3 RESULTS AND DISCUSSION

Overall results on all four tests indicate that synthetic sorbents have the greatest effectiveness against sunken organic chemicals,these sorbents having the highest capacity,lowest water pick-up, and greatest resistance to the destructive nature of the chemicals they sorb.

Release of chemicals back into the water upon retrieval is a major concern when recovering sunken liquids. Imbiber Beads showed the lowest observable release into the water, and the release appeared to come from the package rather than the beads. The synthetic fibre sorbents (Matasorb and 3-M) also showed lower release than the large-pore synthetic foam sorbents (Conwed-D and Graboil). Graboil's release, in fact, was much greater than that of Conwed-D,particularly with the low viscosity chemicals.

The performance of the various sorbents depended much on the viscosities of the materials being recovered. The viscosities and densities of the test liquids are shown in Table 2.

3.1 Sorbent Performance in Test Liquid Alone

Table 3 shows the sorbent capacities in the test liquids alone.

In the more viscous test liquids (creosote,coal tar,and latex) the foam-type synthetic sorbents have much higher capacities .

In the less viscous test liquids, the synthetic fibre sorbents,as well as Conwed and Imbiber Beads, had capacities comparable but still not as high as the foam-type sorbents.

In all test liquids,the capacities of both Oclansorb and activated carbon are well below the other sorbents tested.

When water was used as a test solvent, all sorbents except Graboil and activated carbon demonstrated a hydrophobic nature.

Table 4 compares the results obtained in this part of the study with those obtained in previous Environment Canada sorbent studies (4,5) and to an EPA study on sorbents (6).

Comparisons are made between generic classes of sorbents rather than brands, since the studies used various brands to represent a particular class of sorbent. The studies also used different liquids to test the sorbents and as in the case of coal tar and toluene, liquids that fell into the same family may have quite different properties.

In general the results obtained here compare well with previous results. The exceptions (both with the EPA study) are in treated natural fibers, where the EPA study obtained much lower results, and in cross-linked polymer beads, where the EPA study obtained much higher results.

3.2 Sorbent Performance on Test Chemicals Sunk into Water

Table 5 shows the sorbent capacity, water pick-up, and reusability for each sorbent-liquid pair, and Figures 3.2.1 to 3.2.6 illustrate these results.

3.2.1 Treated Natural Fibre Sorbents

Conwed sorbent pads exhibited high capacity for all the chemicals except for coal tar and latex. These liquids were too viscous to penetrate the fibre. Water pick-up for this sorbent was lower than all but 3-M and Matasorb. However, Conwed pads are not reuseable and do not posses the strength of the synthetic polymer sorbents. Performance of this sorbent was sufficient to continue testing in the flowing water trials.

Oclansorb exhibited a lower capacity for sunken organic chemicals than almost all other sorbents (except activated carbon), water pick-up was high,and this sorbent was not reuseable. Furthermore, the binding material dissolves in the chlorinated aliphatic solvents (1,2-dichloroethane and perchloroethylene) making recovery very difficult in these cases.

This sorbent was not tested further and is not recommended for sunken chemical spills recovery at this time.

3.2.2 Foamed Synthetic Polymer Sorbents

Conwed-D had a higher sorbent capacity for all liquids tested than all sorbents except Graboil. Water pick-up was not unacceptably high although it was higher than the synthetic fibre sorbents and Conwed. This sorbent is strong enough for maximum reuse and loses little of its capacity as it is reused. Conwed-D performed well enough to continue investigating its use.

Graboil, while having the highest capacity for all chemicals tested, had also the highest water pick-up showing little preference for organic chemicals over water.

While its reusability was high for most of the test liquids, strength deteriorated significantly on each reuse. Most importantly, Graboil's large release of chemical on retrieval and high water pick-up prevented it from being considered for further study.

3.2.3 Synthetic Polymer Fibre Sorbents

Both 3-M Type 156 Pads and Matasorb showed moderately high capacity for sunken chemicals compared to the other sorbents and had the lowest levels of water pick-up, in many cases less than 1%. 3-M is not as strong as Matasorb and thus not as reusable,both sorbents lost much of their capacity on reuse. Availability and greater strength made Matasorb the choice for the flowing water trial although 3-M has a greater capacity and should not be ruled out as a possible candidate for further study in sunken chemical spills recovery.

3.2.4 Cross-Linked Polymer Beads

Imbiber Beads had a lower capacity than the synthetic polymer sorbents and the polypropylene packaging material was not well penetrated by the higher viscosity test liquids. Futhermore, the beads cannot be pressed and reused. However these beads are highly hydrophobic and thus have low water pick-up. Most importantly, they do not release the sorbed material.

The versatility of the beads also made them a good candidate for further testing.

3.2.5 Granular Activated Carbon

The granular activated carbon used for this study was more dense than water and thus the easiest of the sorbents to sink. Large size (8 * 30) granular activated carbon was chosen for its easy packaging and to minimize suspension of carbon dust particles in the water. However,as well as having the lowest capacity of all the sorbents tested for every test liquid, the activated carbon released a great deal of dust into the water, which, in the field, could cause respiratory problems for aquatic organisms. This sorbent was not tested further.

3.3 Effect of Flowing Water on Sorbent Performance

The effects of flowing water on the capacity and water pick-up of Matasorb, Conwed, Conwed-D, and Imbiber Beads for the test liquids 1,2-dichloroethane, perchloroethylene "puddle", and 1,2,4-trichlorobenzene are shown in Table 6.

For most sorbent-liquid pairs there were few significant changes in capacity. The small measured gains in capacity of some sorbents could be due to the shorter drip time during testing, lowered viscosity of the liquids as a result of warmer temperatures, and facilitation of pick-up by local currents.

The Imbiber Bead-1,2-dichloroethane and Imbiber Bead-perchloroethylene pairs showed significant losses in capacity although there was no apparent increase in water pick-up when exposed to flowing water and a gravel bottom. The reasons for this are not clear as the sorbent did not release significant amounts of liquid on retrieval.

Only small increases in water pick-up were observed for the other sorbents, with Matasorb performing the best at no significant increase.

Conwed-D had the highest increase, at 29%, over the stagnant water tests when sorbing perchloroethylene "puddle" material. At this level water pick-up is already a significant factor and may increase further when exposed to a greater current.

The water pick-up for Conwed also increased slightly but this may be due to deterioration of the hydrophobic treatment chemical of the pad evident at this stage of testing.

3.4 Fate of Small Spills in Tank

This test was performed to gain insight into how much of a spill can actually be recovered by sorbents. The results shown in Table 7 reflect not only the sorbent's ability to sorb from the gravel bottom, but the test liquid's ability to penetrate it. As well there may be losses of spilled test liquid due to dispersion and evaporation.

Perchloroethylene completely penetrated the gravel bottom, thus making contact with the sorbents impossible. Penetration of the bottom material will greatly depend on the natures of both the bottom and the sunken liquid.

Results for Conwed pads are incomplete as the pads were no longer usable at this point in the testing. This may be due to deterioration of the treatment material, possibly because of the high summer temperatures.

Matasorb, Conwed-D, and Imbiber Beads all showed good pick-up of 1,2-dichloroethane and 1,2,4-trichlorobenzene. Matasorb demonstrated the highest recovery at an average of 78% liquid recovery. It is possible the pick-up is greatest for Matasorb because this sorbent is the least rigid of the sorbents tested, while the Imbiber Bead packet, the most rigid, had the lowest pick-up. A stiff sorbent would be less able to contact well with an uneven surface,such as those found on the bottoms of lakes and rivers.

TABLE 2 VISCOSITY AND DENSITY OF TEST LIQUIDS

Test Liquid	Viscosity (mPa.s)	Density (g/ml)
1,2-dichloro-ethane	0.89	1.25
perchloro-ethylene	0.93	1.60
1,2,4-trichloro-benzene	2.4 @ 26°C	1.45
creosote	23	1.01
coal tar	4600	1.07
latex*	/	1.2

*viscosity not available

TABLE 3 SORBENT CAPACITY IN TEST LIQUID ALONE (g/g)

SOLVENT	SORBENT							
	Conwed	Oclan-sorb	Graboil	Conwed D	Mata-sorb	3-M	Imbiber Beads	Act. Carbon
Water	0.6	1.1	19	2.2	0.6	0.4	1.2	1.3
1,2-dichloro-ethane	11.3	3.8	22.5	13.9	10.1	13.7	7.7	1.1
Perchloro-ethylene	13.7	5.7	33	27	14	18	10	1.5
1,2,4-Tri-chloro-benzene	14.4	4.4	21	23	12.1	14.0	12.1	1.3
Creosote	10.0	2.9	29	18.8	8.2	10.1	3.8	1.1
Coal Tar	*	3.7	52	32	13	17	**	**
Latex	**	**	26	40	**	**	**	**

* sorbent collapsed durring retrieval
** test liquid did not completely penetrate sorbent

TABLE 4 COMPARISON OF REPORTED SORBENT CAPACITIES

Chemical Class	Study Quoted	Representative Liquid	Generic Sorbent Class TNF	CLP	PE	PP	PU
Aliphatics, Halogenated	Present Study	1,2-dichloroethane	3.7,11.3	7.7	16.0,13.7	10.1	22.5
		perchloroethylene	5.7,13.7	10.0	27.0,18.0	14.0	33
	EPA (6)	trichloroethylene	2.2	36.9	25.6	11.3	20.4
Aromatics, Halogenated	Present Study	1,2,4-trichlorobenzene	4.4,14.4	12.1	23.0,14.0	12.1	21.0
	EPA (6)	o-dichlorobenzene	2.0	29.6	22.3	11.2	19.2
Aromatic Hydrocarbons	Present Study	coal tar	3.7,15.2	NA	32.3,17	13	52
	EPA (6)	toluene	1.4	18.3	17.6	8.3	12.6
	EPS (4,5)	toluene	10.9	2.9*	22.9,12.5	9.8	22.0
Phenols and Cresols	Present Study	creosote	2.9,10.0	3.8	18.8,10.1	8.2	29
	EPA (6)	cresol	2.0	13.9	17.2	10.0	INC
Water	Present Study	water	1.1,0.6	1.2	2.2,0.6	0.4	19
	EPA (6)	water	1.0	2.5	1.4	0.1	2.4
	EPS** (4,5)	water	0.69	0.0	2.7,0.3	0.1	3.0

*value for diesel fuel
**water pick-up reported in the presence of test liquid
TNF-treated natural fibre (present study-Oclansorb,Conwed)
CLP-cross-linked polymer beads (Imbiber Beads)
PE-polyethylene (present study-Conwed-D,3-M type 156)
PP-polypropylene (present study-Matasorb)
PU-polyurethane (present study-Graboil)

TABLE 5: SORBENT CAPACITY, WATER PICK-UP, AND REUSABILITY IN WATER

TEST LIQUID	SORBENT	SORBENT CAPACITY(g/g)	% WATER PICK-UP	REUSES
1,2-dichloro-ethane	Conwed	12.0	3	0
	Oclansorb	cp	-	-
	3M 156	12.4	2	4
	Matasorb	8.8	9	8
	Conwed-D	13.6	15	8
	Graboil	21.1	25	3
	I.Beads*	7.4	na	0
	GAC*	1.9	na	0
Perchoro-ethylene "puddle"	Conwed	15.9	11	0
	Oclansorb	2.8	73	0
	3M 156	18	12	2
	Matasorb	14.2	8	5
	Conwed-D	24.3	38	10
	I.Beads	10.8	na	0
	GAC	2	na	0
1,2,4-trichloro benzene	Conwed	11.5	21.0	0
	Oclansorb	2.9	64	0
	3M 156	14.7	12	2
	Matasorb	11.4	3	4
	Conwed-D	19.9	17	10
	Graboil	23.2	33	8
	I.Beads	6.1	na	0
	GAC	1.6	na	0
Creosote	Conwed	10.2	1	0
	Oclansorb	3.4	1	0
	3M 156	12.1	1	2
	Matasorb	8.2	1	10
	Conwed-D	14.9	9	10
	Graboil	19.5	17	10
	I.Beads	4.1	na	0
	GAC	1.6	na	0
Coal Tar	Conwed	cp	-	-
	Oclansorb	2.1	32	0
	3M 156	17.5	2	0
	Matasorb	13.2	1	3
	Conwed-D	16.9	28	3
	Graboil	41.4	22	1
	I.Beads	np	-	-
	GAC	np	-	-
Latex**	Conwed-D	18.0	na	10
	Graboil	30	na	10

* capacity includes that of the sorbent packaging
**only Conwed-D and Graboil penetrated
cp-sorbent collapsed np-sorbent not penetrated
na-not applicable

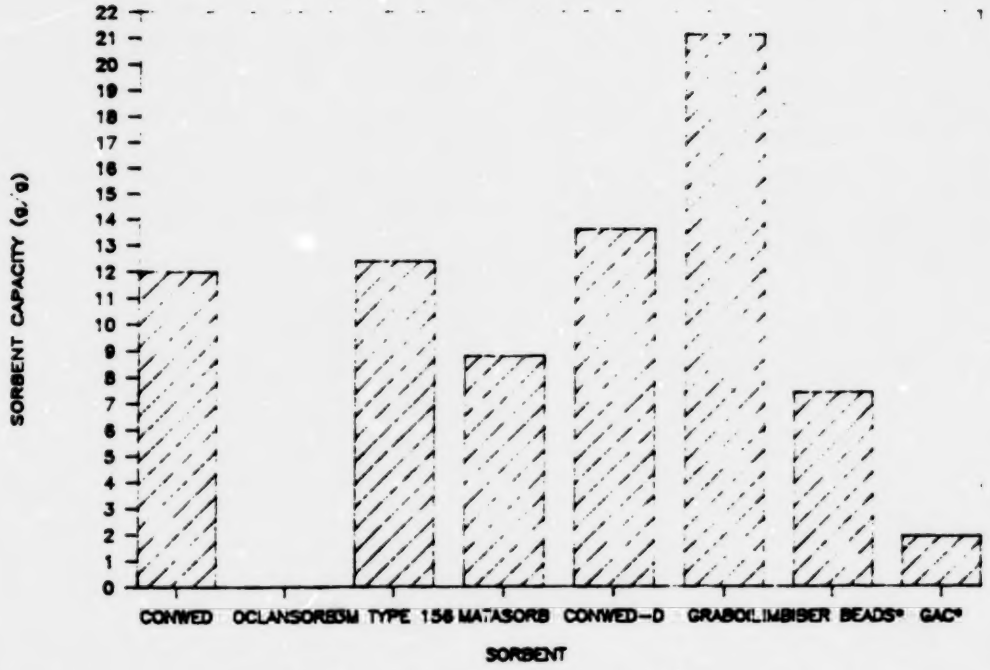

FIGURE 3.2.1.1 Sorbent Capacity in 1,2-Dichloroethane and Water

FIGURE 3.2.1.2 Water Pick-up in 1,2-Dichloroethane and Water

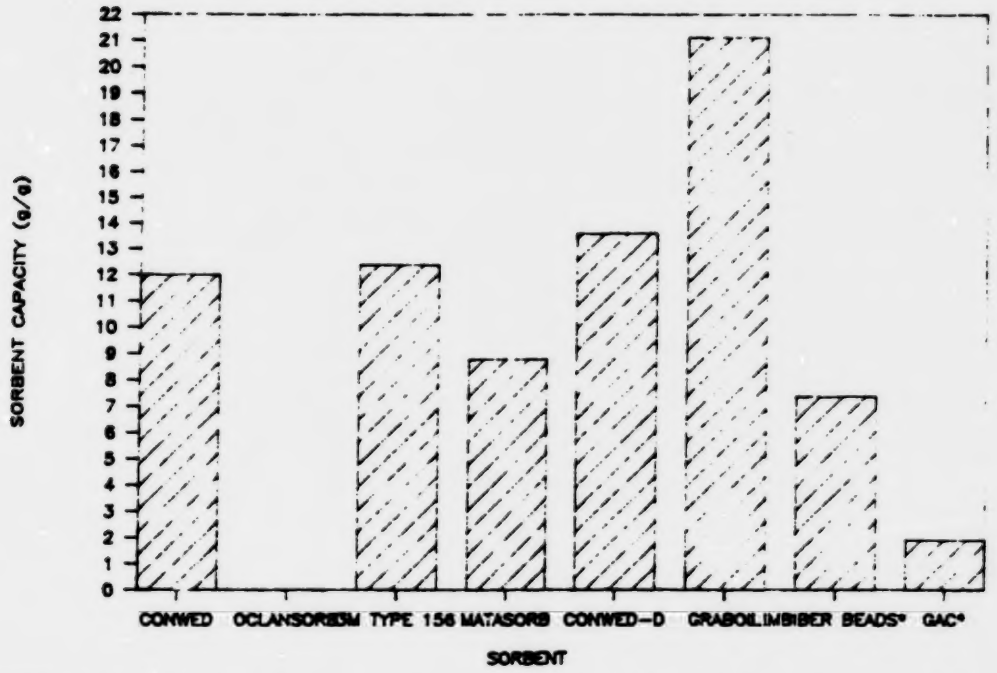

FIGURE 3.2.2.1 Sorbent Capacity in Perchloroethylene "Puddle" and Water

FIGURE 3.2.2.2 Water Pick-up in Perchloroethylene "Puddle" and Water

FIGURE 3.2.3.1 Sorbent Capacity in 1,2,4-Trichlorobenzene and Water

FIGURE 3.2.3.2 Water Pick-up in 1,2,4-Trichlorobenzene and Water

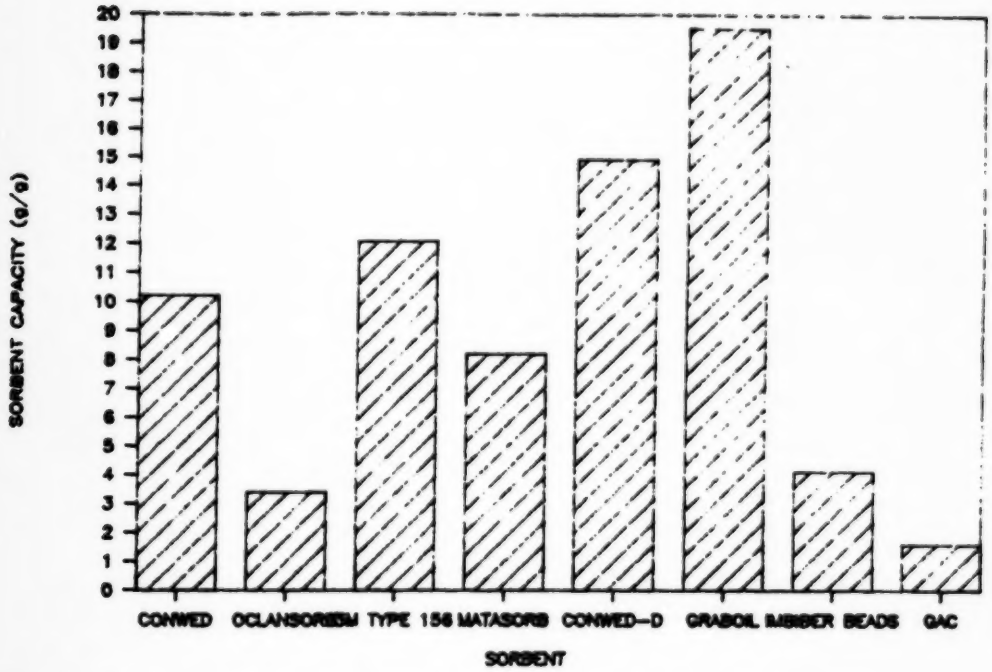

FIGURE 3.2.4.1 Sorbent Capacity in Creosote and Water

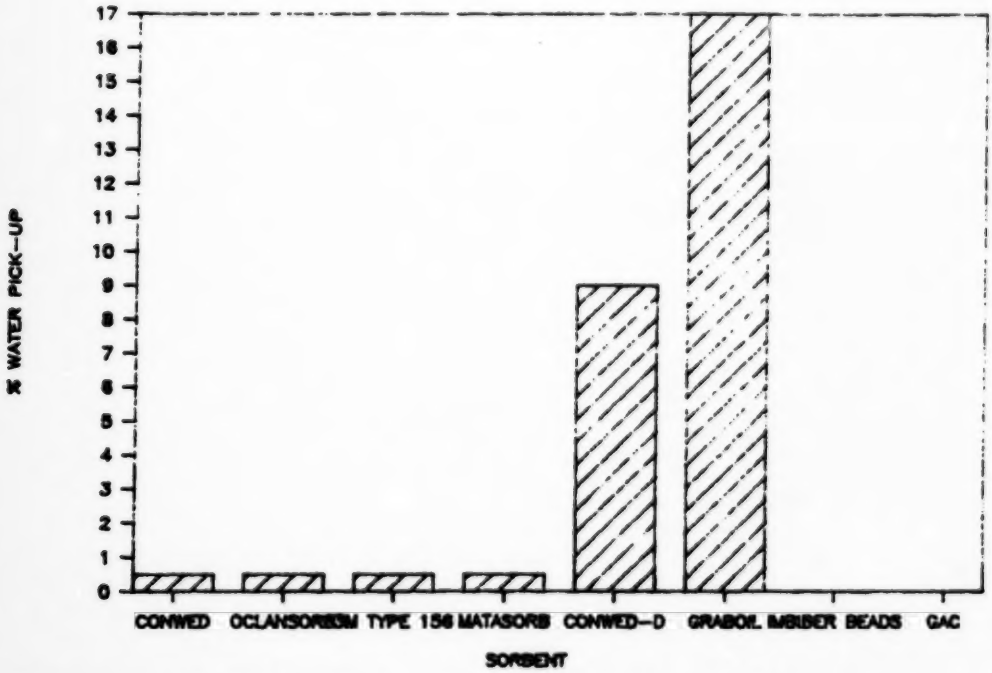

FIGURE 3.2.4.2 Water Pick-up in Creosote and Water

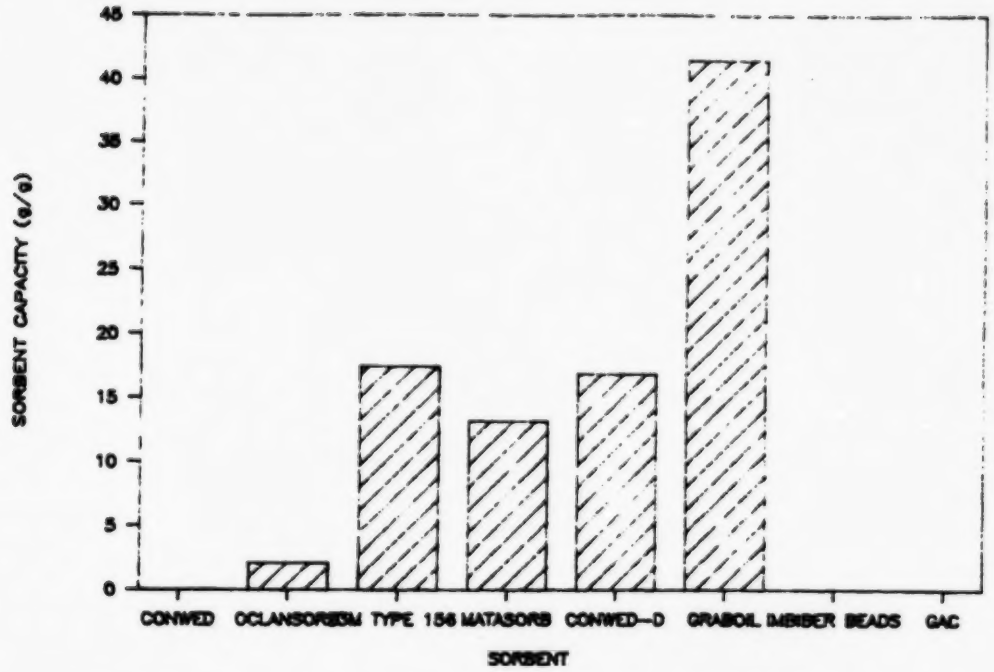

FIGURE 3.2.5.1 Sorbent Capacity in Coal Tar and Water

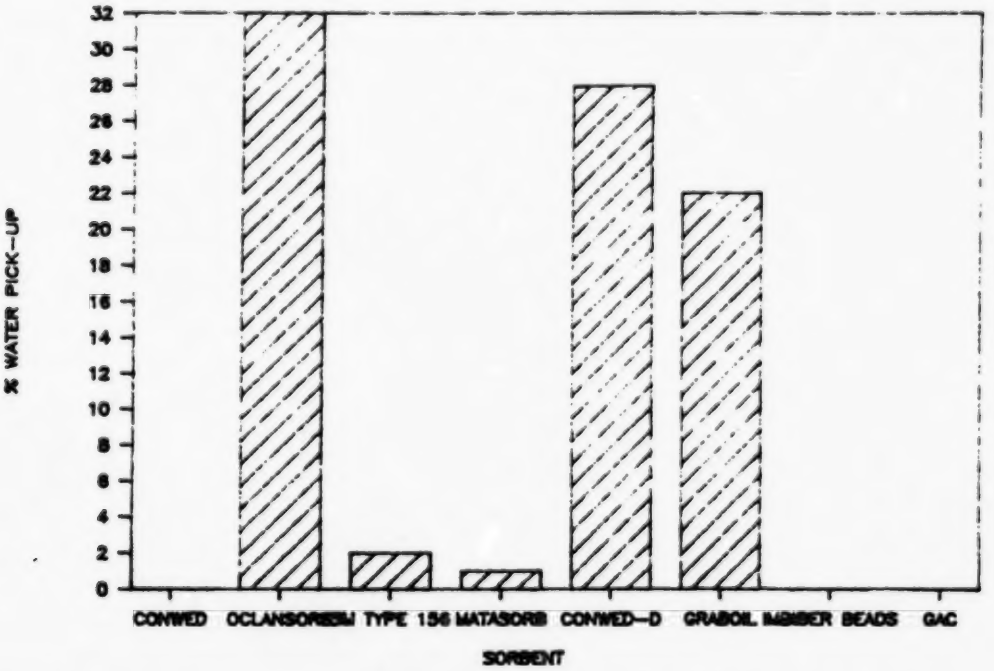

FIGURE 3.2.5.2 Water Pick-up in Coal Tar and Water

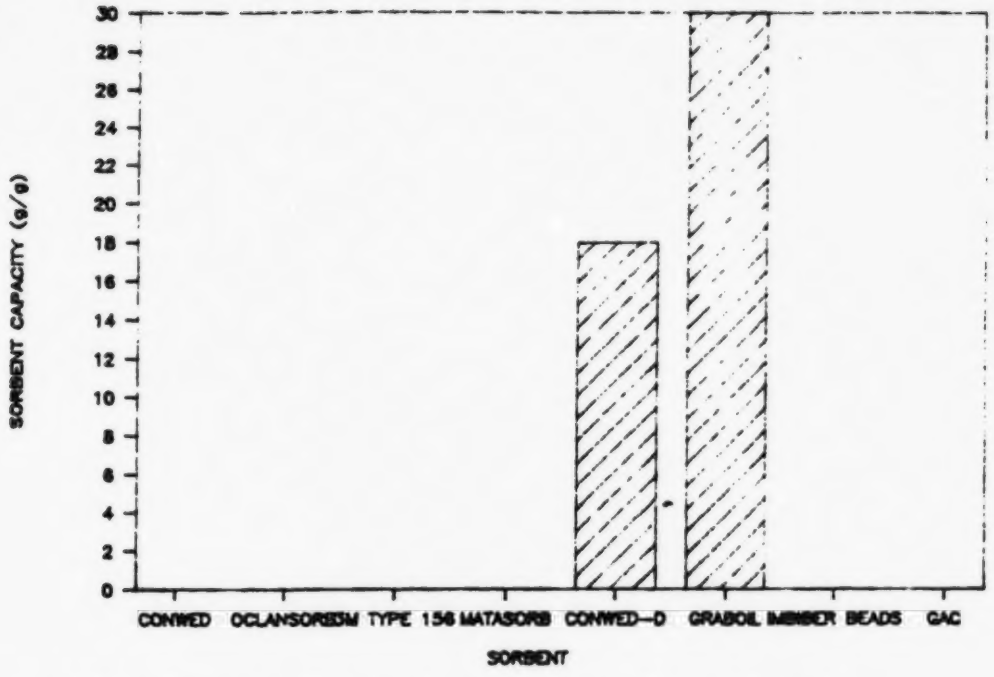

FIGURE 3.2.6.1 Sorbent Capacity in Latex and Water

TABLE 6 COMPARISON OF SORBENT CAPACITY AND WATER PICK-UP,IN STAGNANT AND FLOWING WATER

SORBENT	LIQUID	SORBENT CAPACITY STAG. WATER (g/g)	SORBENT CAPACITY FLOW. WATER (g/g)	% WATER PICK-UP STAG. WATER	% WATER PICK-UP FLOW. WATER	CHANGE IN FLOWING WATER CAPACITY	CHANGE IN FLOWING WATER % PICK-UP
MATASORB	ED	8.8	9.7	9.0	4.0	+10%	-5%
	PERC	14.2	14.7	8.0	10.0	+4%	+2%
	1,2,4-TCB	11.4	12.4	3.0	4.0	+9%	+1%
CONWED	ED	12.0	11.2	3.0	18.0	-7%	+15%
	PERC	15.9	13.4	11.0	19.0	-16%	+8%
	1.2,4-TCB	11.5	14.1	21.0	13.0	+23%	-8%
CONWED-D	ED	13.6	13.7	15.0	15.0	+1%	0%
	PERC	24.3	20.9	9.0	38.0	-14%	+29%
	1,2,4-TCB	19.9	20.8	8.0	17.0	+5%	+9%
IMBIBER BEADS	ED	7.4	5.4	na	na	-27%	na
	PERC	10.8	7.9	na	na	-27%	na
	1,2,4-TCB	6.1	6.1	na	na	0%	na

ED ; ethylene dichloride
PERC ; perchloroethylene
1,2,4-TCB ; 1,2,4,-trichlorobenzene

TABLE 7 FATE OF SMALL SPILL IN TANK

Test Liquid	Sorbent	% Recovery
1,2-dichloro-ethane	Matasorb	73
	Conwed	**
	Conwed-D	65
	Imbiber Beads	69
Perchloro-ethylene	Matasorb	<1
	Conwed	**
	Conwed-D	<1
	Imbiber Beads	<1
1,2,4-trichloro-benzene	Matasorb	83
	Conwed	**
	Conwed-D	75
	Imbiber Beads	64

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